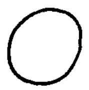
FLUID MECHANICS AND BASEBALL



9 inches in circumference

5 ounces

$$R = \frac{\rho \cdot V \cdot r}{\eta}$$

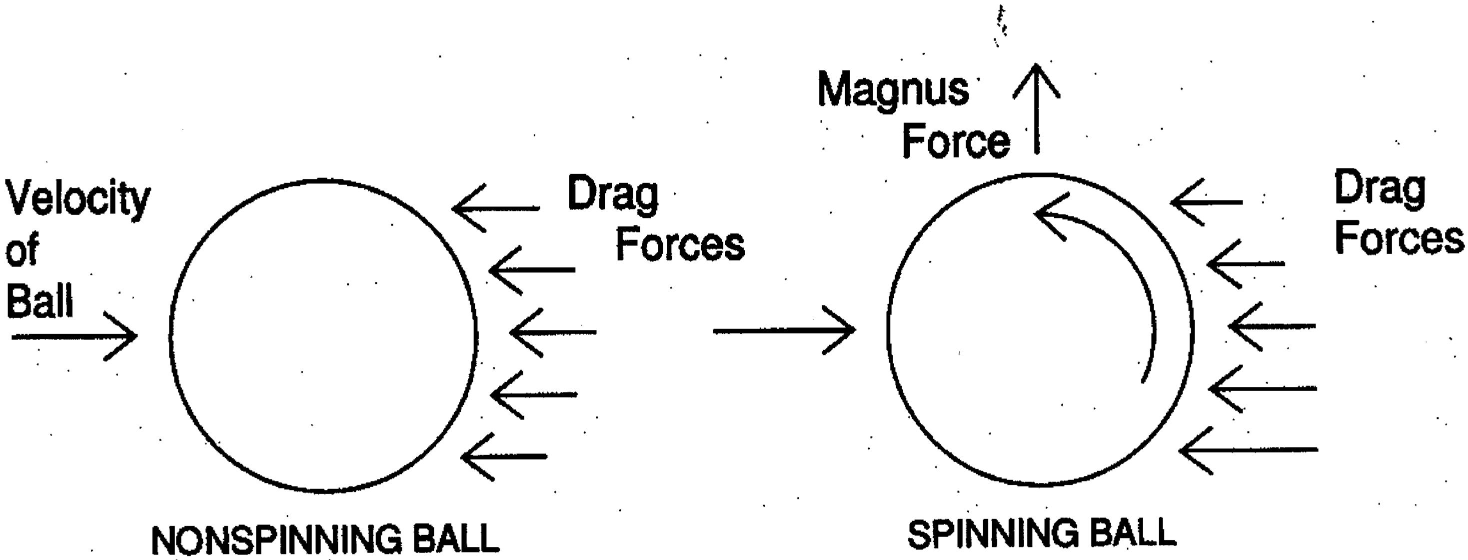
Reynolds number

ρ fluid (air) density

η viscosity

r diameter

$\sim 2200\,V$ for baseball V in mph



$$F_d = \frac{1}{2} C_d \, \rho \cdot A \cdot V^2$$

$$A = \pi r^2$$

C_d can depend on V for large velocities

$$F_m = K \cdot f \; V \cdot C_d$$

in pounds

mph

$K \sim 2 \times 10^{-6}$

rotation f is measured in rpm

Almost all of fluid dynamics follows from the partial differential equation called the Navier - Stokes equation

Has not, in practice, led to analytic solutions of real problems of any complexity

In this sense, the curve of a baseball is not understood. Navier - Stokes equation applied to a baseball has not been solved.

Can be done numerically at smaller Reynolds numbers

Eminent physicist: "There are two unsolved problems which interest me deeply. The first is the unified field theory; the second is why does a baseball curve? I believe that, in my lifetime, we may solve the first, but I despair of the second"

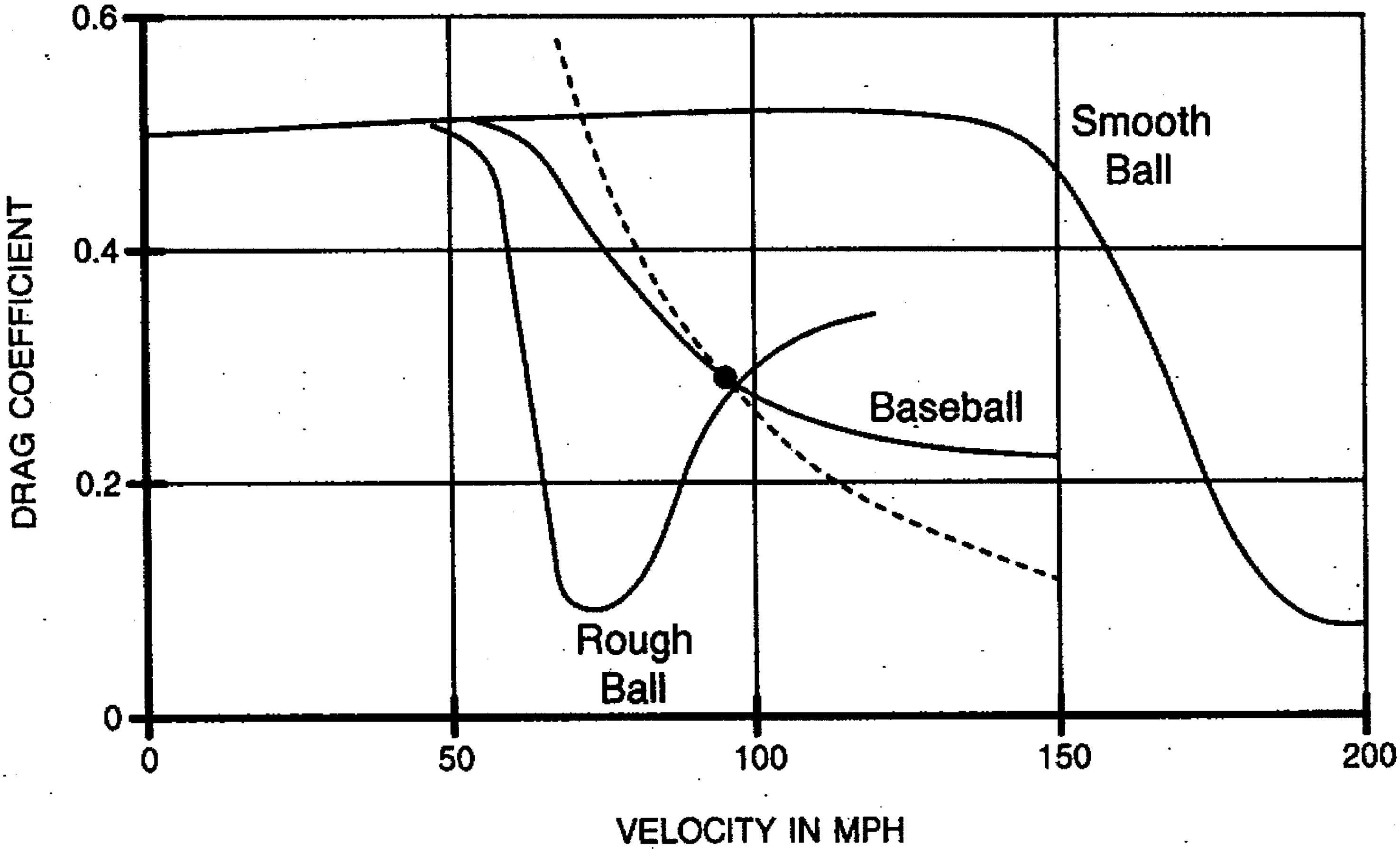
$$\rho\left[\frac{\partial \vec{V}}{\partial t} + (\vec{V}\cdot\vec{\nabla})\vec{V}\right] = -\operatorname{grad} p + \eta\,\Delta\vec{V}$$

$$+ \left(\zeta + \frac{1}{3}\eta\right)\operatorname{grad}\operatorname{div}\vec{V}$$

NAVIER - STOKES $\qquad$ ζ second viscosity

- The velocity dependence of the drag coefficient for large velocities
- At the broken line the force on the ball equals gravity

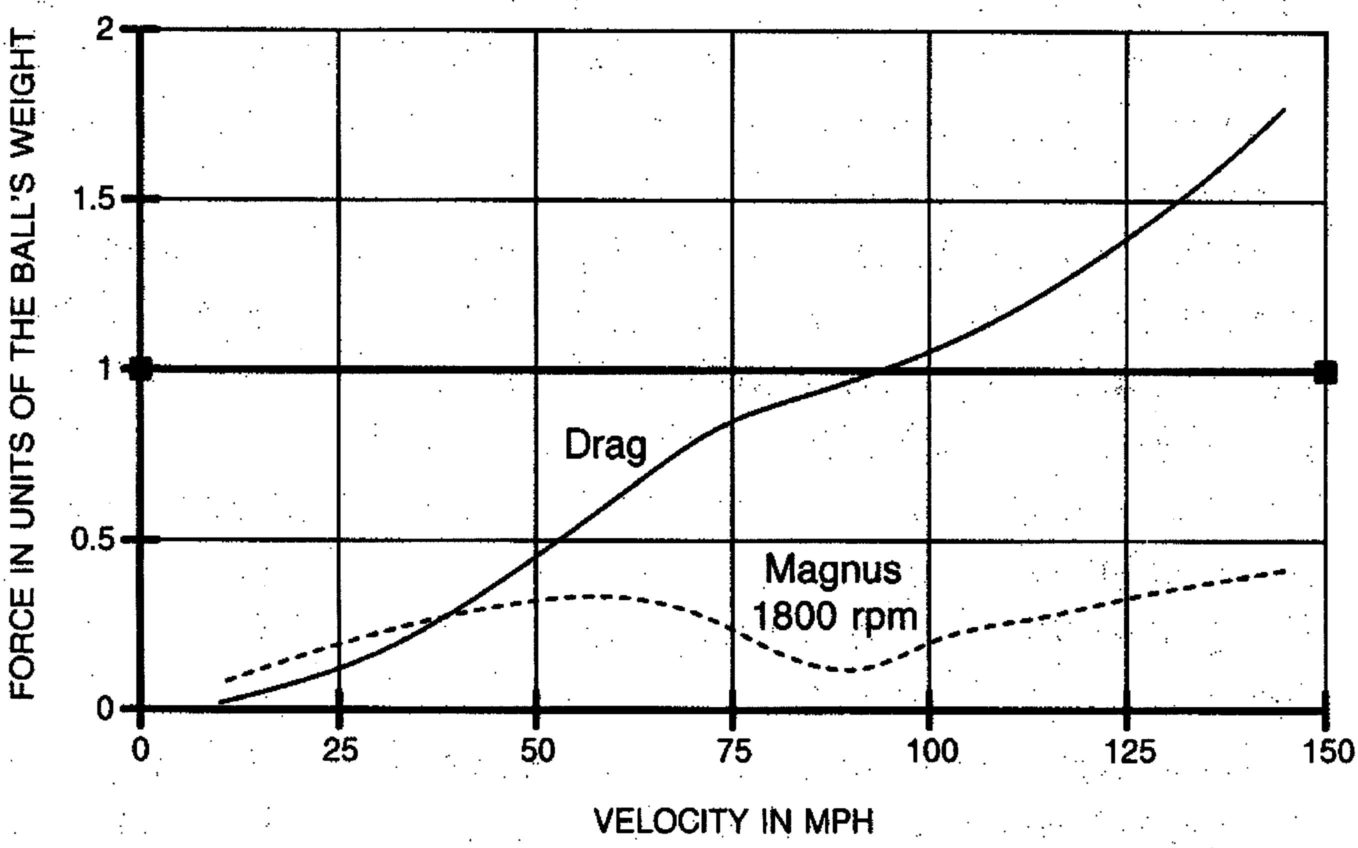
rough ball: completely covered with stitches



50 to 130 mph velocity range is relevant for baseball

Fast baseball is on the verge of turbulence

The solid line shows the variation with velocity of the drag force on a baseball. The broken line shows the variation with velocity of the Magnus force for a ball spinning at a rate of 1800 rpm.
The forces are expressed in units of the ball's weight.



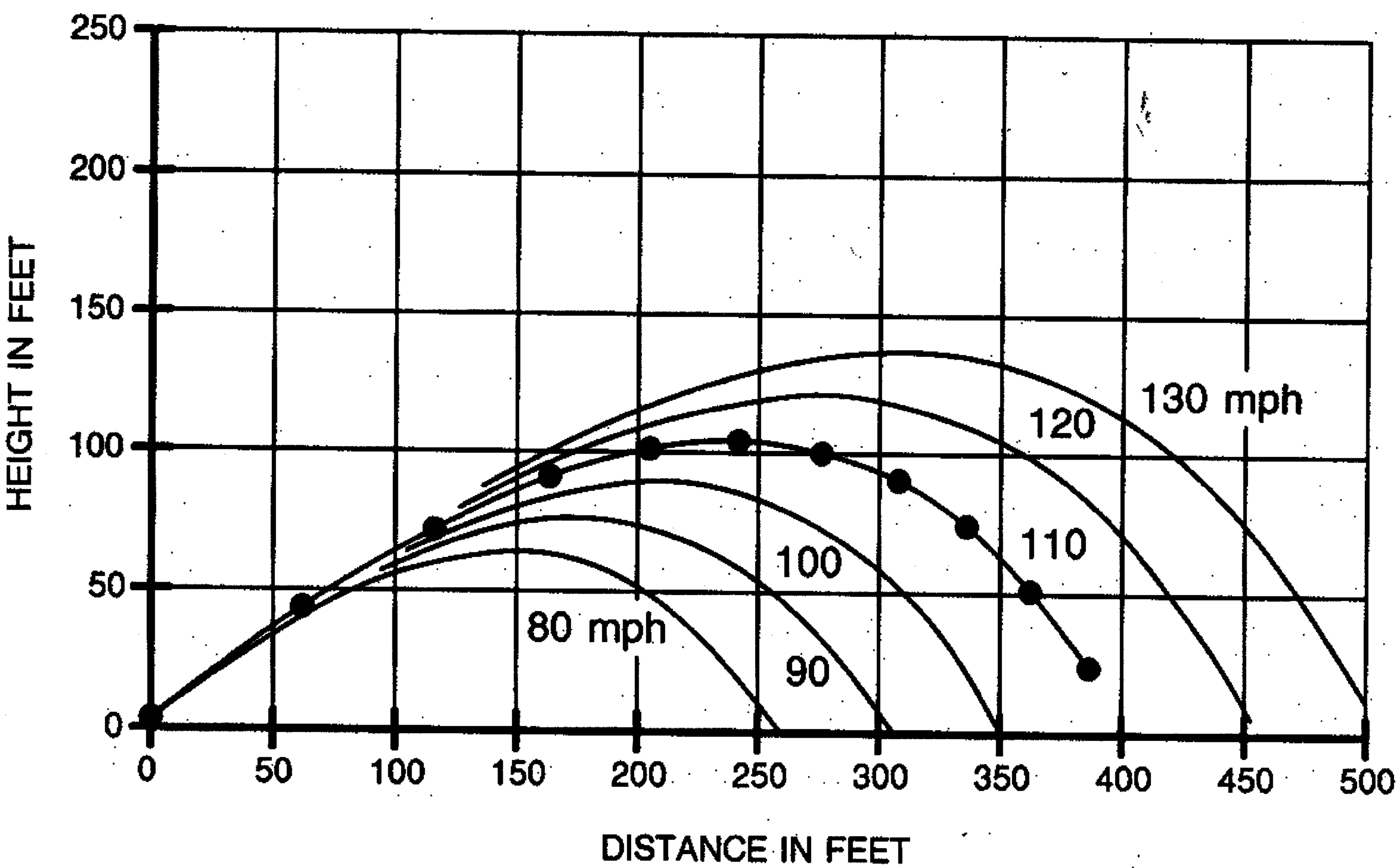
$$F_m = K f V C_d \left[1 + 0.5 \times \frac{V}{C_d} \times \frac{dC_d}{dV} \right]$$

Magnus force at large velocities

at $\frac{V}{C_d} \times \frac{dC_d}{dV} = -2$ sign reversal

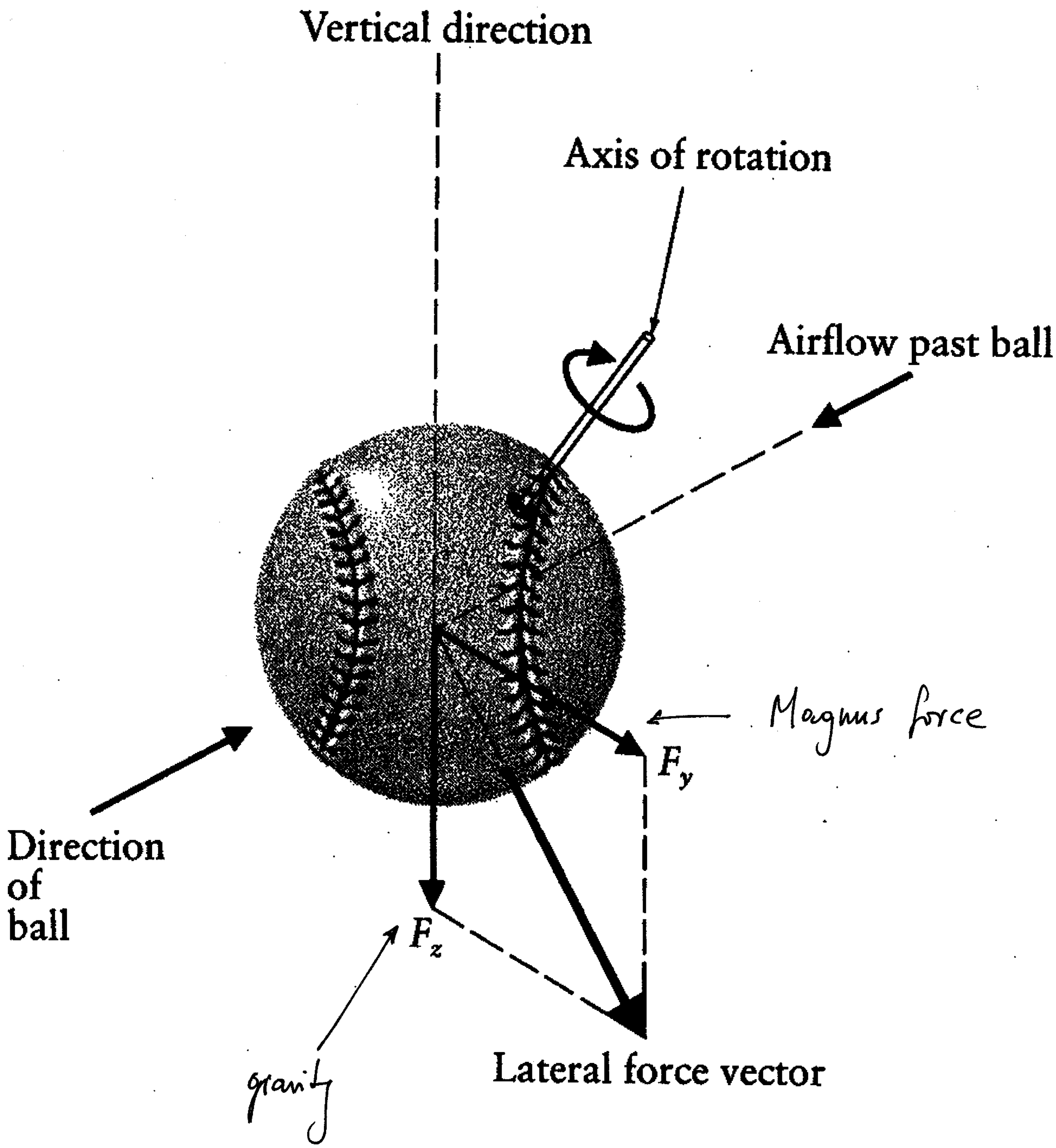
The trajectory of balls projected at an angle of 35° with different velocities

Balls are assumed to be rotating with initial backspin of ~ 1800 rpm (one revolution per 5 feet at 100 mph)



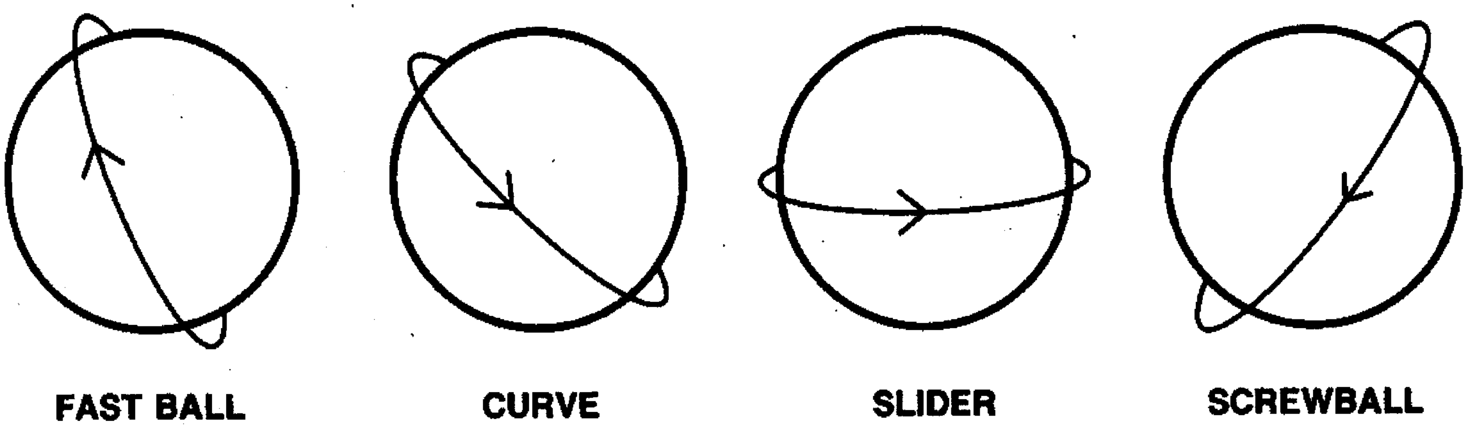
With rotation distance is increased about 20 feet.

Coors field baseball



Vertical direction
Axis of rotation
Airflow past ball
Magnus force
F_y
Direction of ball
F_z
gravity
Lateral force vector

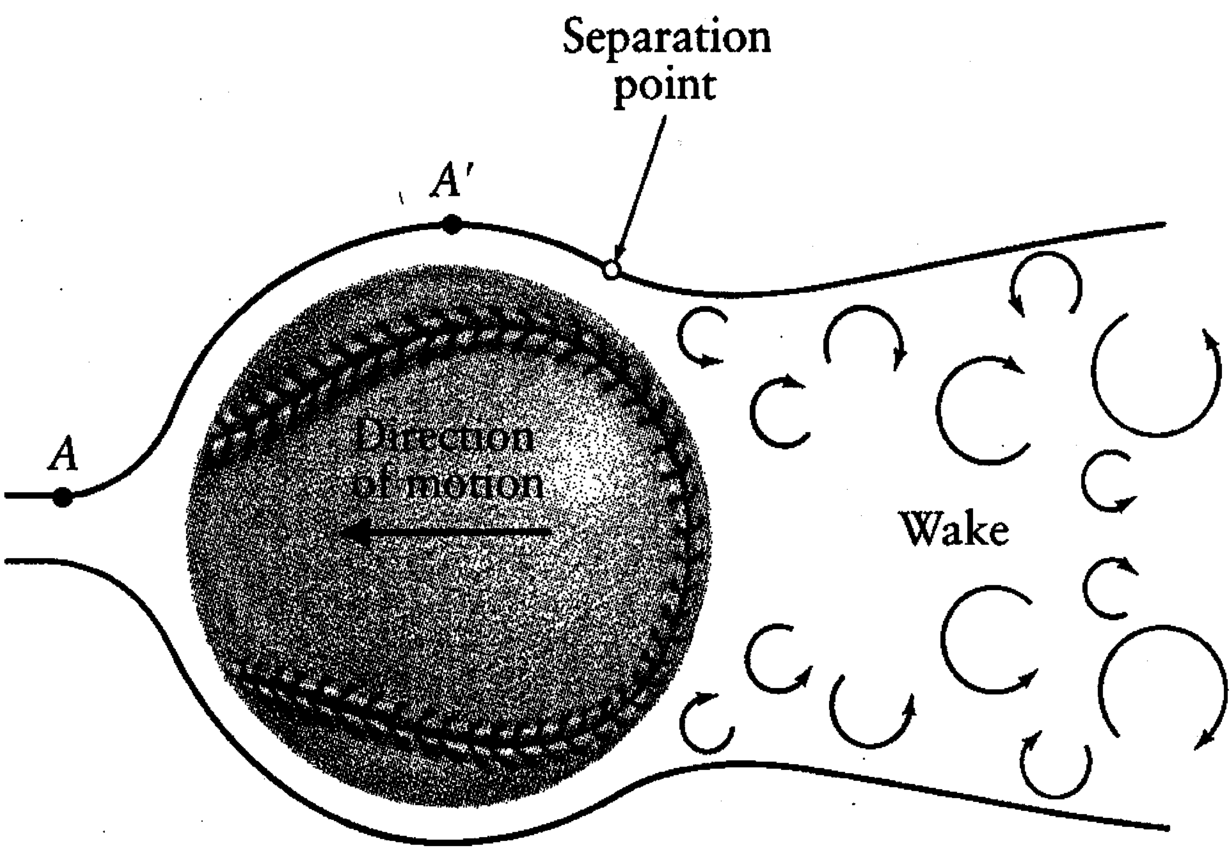
Magnus force is in the direction of arrows
Baseball is coming at you (batter)



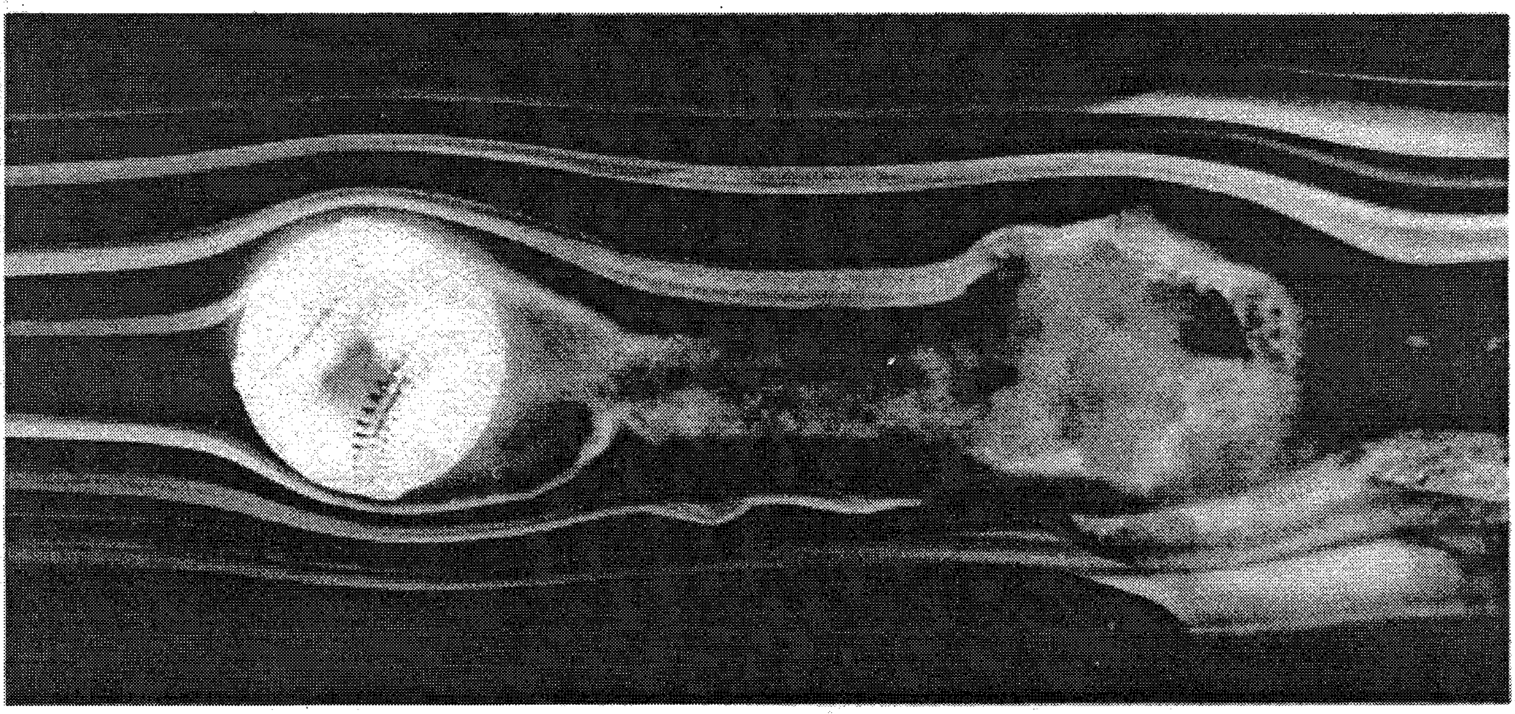
Boundary Layer

Wake field

Turbulence



Realistic Wind Tunnel picture



Movie at smaller Reynolds numbers